REMARKS

Applicants respectfully request reconsideration and allowance in view of the foregoing amendments and following remarks. By this response, claims 1-2, 4, 19-20 and 22 have been amended to further clarify the invention. After entry of this response, claims 1-8 and 19-26 will be pending in the application.

In the Office Action, the Examiner rejected claims 1-8 and 19-26, claims 9-18 and 27-36 having been finally withdrawn from consideration.

103(a) Rejections

In the Office Action, the Examiner rejected claims 1-8 and 19-26 under 35 U.S.C. §103(a) as allegedly being unpatentable over any one of the patents to Ladabaum et al. ('351, '452, '709), the patents to Haller et al. ('476, '832), or the article Ladabaum et al., when taken in view of Horner et al. ('652) and Swierkowski ('580). Applicants respectfully traverse the rejections.

A §103(a), or obviousness, rejection is proper only when "the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time of the invention was made to a person having ordinary skill in the art to which the subject matter pertains." 35 U.S.C. §103(a). The Examiner must make out a prima facie case for obviousness. The *en banc* Federal Circuit has held that "structural similarity between claimed and prior art subject matter, proved by combining references or otherwise, where the prior art gives reason or motivation to make the claimed compositions, creates a prima facie case of obviousness." *In re Dillon*, 16 U.S.P.Q. 2d 1897, 1901 (CAFC 1990). The underlying inquiries into the validity of an obvious rejection are: "(1) the scope and content of the prior art; (2) the level of ordinary skill in the prior art; (3) the differences between the claimed invention and the prior art; and (4) objective evidence of nonobviousness." *In re Dembiczak*, 175 F.3d 994, 998, (Fed. Cir. 1999).

Further, the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the

combination. *In re Mills*, 916 F.2d 680, 16 U.S.P.Q.2d 1430 (Fed. Cir. 1990). Likewise, if the proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. *In re Gordon*, 733 F.2d 900, 221 U.S.P.Q. 1125 (Fed. Cir. 1984).

Finally, with hindsight, a claim of obviousness can be an easy one to make. Many inventions seem obvious with the clarity of 20-20 hindsight. However, a hindsight basis for obviousness is inappropriate and cannot sustain a *prima facie* case of obviousness. Applicants' respectfully assert that the Examiner is judging obviousness of Applicants' invention using hindsight, and as such, should reconsider the rejections from the proper perspective of the time of Applicants' invention, without the teachings of Applicants' disclosure.

For the reasons stated below and taking into consideration the standards for obviousness presented above, Applicants assert that one of ordinary skill in the art would not have considered Applicants' invention obvious at the time of invention and, therefore, that Applicants' rejected claims 1-8 and 19-26 are not obvious over the prior art of record.

Independent Claims 1 and 19

Applicants' independent claim 1, as amended, recites an acoustic transducer assembly that includes:

> a substrate having a topside and a backside;
> a microfabricated acoustic transducer formed on the topside of the substrate; and
> a damping material disposed on the backside of the substrate, the damping material having an acoustic impedance substantially equal to that of the substrate and suppressing substrate acoustic modes.

Applicants' independent claim 19, as amended, recites a method for suppressing acoustic modes that includes:

> providing a substrate having a topside and a backside;
> forming a microfabricated acoustic transducer on the topside of the substrate; and
> placing a damping material on the backside of the substrate, the damping

material having an acoustic impedance substantially equal to that of the substrate and suppressing substrate acoustic modes.

At the time of Applicants' invention, as contrasted with the cited prior art, acoustic damping for specific, narrow substrate modes in a microfabricated ultrasonic transducer (MUT) was not contemplated because, until Applicants first observed these specific modes, it was unknown, and therefore not obvious, that they existed in MUTs and therefore required suppression. In fact, at the time of Applicants' invention, it was widely believed in the art of MUTs that they radiated acoustic energy only outward from the surface of the moving diaphragm (in contrast to the volumetric expansion and contraction of piezoelectric transducers that radiate acoustic energy at all surfaces) and that, therefore, substrate modes did not exist. Not needing damping material was touted as an advantage of MUTs over piezoelectric transducers.

Further, after discovering the detrimental specific, narrow substrate modes in MUTs, Applicants' had to investigate and discover the damping material of the present application. Backing materials, as used in piezoelectric transducers, are required to have a low acoustic impedance as compared to the transducer material so as to not reduce the sensitivity of the device (see, for example, the Examiner's cited prior art of Horner, col. 1, ll. 21-32). Applicants' invention includes the discovery, not only of the specific, narrow substrate modes in the MUTs, but also that the MUT backing material needed an acoustic impedance substantially similar to that of the transducer substrate material. As known in the art of piezoelectric transducers, using a backing material with an acoustic impedance as high as Applicants' backing material will severely reduce the sensitivity of the piezoelectric device.

Therefore, Applicants' invention consists of first realizing that such specific substrate modes existed and were problematic. Then, given the universe of potential solutions to this newly discovered problem (e.g., roughening the substrate, changing electrodes, changing support structures, etc.), Applicants' converged on the present invention (i.e., that an appropriately engineered and manufactured damping material having an acoustic impedance substantially similar to that of the transducer substrate material would be effective in damping the newly-discovered, specific substrate modes). Furthermore, Applicants' have demonstrated the detrimental effects of the discovered specific substrate modes and the effectiveness of their

solution with experimental data, as illustrated in Figures 4A-4D of the present application.

With respect to the Ladabaum et al. patents ('351, '452, '709) and the Haller et al. patents ('476, '832), it would not have been obvious to those skilled in the art at the time of Applicants' invention that the damping of substrate acoustic modes in a MUT would be necessary. In fact, these references do not contain a single example where substrate acoustic mode ringing is evident and therefore cannot suggest or imply the prospect that such acoustic modes would be problematic. Therefore, one skilled in the art of MUTs, at the time of Applicants' invention, would not have considered adding a damping material to a MUT substrate to suppress substrate acoustic modes because these modes were unknown in the art of MUTs. For at least this reason, independent claims 1 and 19 are not unpatentable as being obvious over the Ladabaum et al. patents ('351, '452, '709) and the Haller et al. patents ('476, '832).

In considering the Ladabaum et al. article in view of the Horner et al. ('652) patent and the Swierkowski ('580) patent, the difference between piezoelectric transducers and MUTs is significant and an understanding of each is critical. A piezoelectric transducer, being a bulk device, is known, due to volume conservation, to generate particle motion, not only at its primary radiating surface, but also at the surface opposite of its primary radiating surface, and even at orthogonal surfaces (see, for example, the Horner's teaching at col. 1, ll. 21-32). This particle motion occurs at all frequencies of operation, and has frequency dependencies upon the geometry of the piezoelectric crystal. To make high performance piezoelectric transducers, the energy radiated into supporting structures by this particle motion must be damped, or otherwise counteracted or controlled. However, MUT design is fundamentally different and the technology of piezoelectric transducers is not directly transferable thereto. Therefore, Applicants' assert that the Examiner is incorrect in using suggestions from a piezoelectric transducer disclosure in combination with MUT references to form an obvious rejection.

Microfabricated ultrasonic transducers have a thin and relatively light membrane, suspended over an evacuated cavity, that is actuated by electrostatic force. MUTs are microfabricated using semiconductor processing techniques. It is therefore not evident that particle motion will be created at any point other than where this membrane is vibrating. Applicants' claimed invention is the insightful result of detailed observations made after very

extensive experimentation. From these observations, Applicants' determined that due to the supporting structures of the membrane and the forces transferred to the substrate electrode, certain specific acoustic modes were in fact excited in the silicon substrate. These specific acoustic modes have frequency dependencies based on the *substrate's* geometry, not the geometry of the transduction element as in piezoelectric transducers. These acoustic modes and their dependencies had not been observed prior to Applicants' very extensive experimentation, represented by Figures 4A-4D of the present application, and are not suggested or implied in the cited prior art.

There is substantial prior art, such as Homer et al. ('652), regarding damping piezoelectric transducers. Piezoelectric transducer damping materials must "have low acoustic impedances when compared to transducer material impedance so as to not reduce transducer over-all sensitivity." (Homer, col. 1, ll. 29-32). Further, the list of suggested piezoelectric damping materials provided in Homer, col. 3, ll. 24-51, shows acoustic impedances in the range of from 1.6 MRayls to 5.3 MRayls, with mixture ratios of 1:6 maximum (epoxy to material, by weight). Acoustic impedances in the 2 Mrayls range, as contemplated in the prior art, are used for damping energy radiating from the piezoelectric elements in unintended directions. Damping the piezoelectric element with a much higher impedance, thereby matching that of the transducer material itself (which is typically 10's of Mrayls), would make for a very inefficient (if not totally useless) transducer by reducing the energy radiating from the piezoelectric element in its intended direction.

In contrast, Applicants' discovered that to minimize the effects of the newly-discovered detrimental substrate modes, the added damping material should have an acoustic impedance substantially equal to the transducer substrate material. The types of backing described in Homer et al. ('652) have acoustic impedances so low that they would do nothing to kill the specific acoustic modes first observed in Applicants' MUT substrate. For instance, it is widely know in the art that a silicon substrate has an acoustic impedance of about 20 MRayls. Backing material with this high of an acoustic impedance would never have been obvious to those skilled in the art at the time of applicants' invention. Further, an example of Applicants' backing material contains about 1:20 (epoxy to material, by weight).

Unique to Applicants' MUT damping approach is that only a very specific set of narrow acoustic modes is of interest. Thus, a backing that is lossy enough and matched to the acoustic impedance of the silicon substrate (i.e. ~20 Mrayls) does work to damp the specific substrate acoustic modes without having the adverse affect of reducing the energy from the transduction element in its intended direction, as would be the case in the cited prior art.

Regarding Swierkowski ('580), this reference also relates to a piezoelectric transducer, and particle motion is directed towards the channels. It could have been anticipated in Swierkowski ('580) that damping would be required in its configuration, because particle motion is occurring in all directions due to the action of the piezoelectric element (that is why absorbers 46 and 47 are taught). Furthermore, in Swierkowski ('580), the energy of the piezoelectric element is designed to go *towards the substrate*. Also, there is a relatively incompressible fluid in Swierkowski ('580) that would be expected to transmit a substantial portion of the piezoelectric element's energy to the substrate. Furthermore, Swierkowski ('580) does not teach specifics about the absorbers 46 and 47 in an otherwise specific teaching, and thus in no way teaches or implies the matched, lossy, damping material of the present invention.

By contrast, in Applicants' MUT case, the transduction element's energy, except for the very specific acoustic modes transmitted through electrode and supporting structure forcing functions first observed through Applicants' experimentation, is designed to radiate from the transducer's surface in a direction away from the substrate. Also, the MUT does not have incompressible fluid. Instead the MUT has an evacuated cavity between the vibrating membrane and the substrate. One skilled in the art would not expect the mechanical motion of the membrane to transmit its energy through the evacuated cavity towards the substrate, as would be analogous to the piezoelectric transducers of the cited prior art.

Therefore, for at least these reasons, independent claims 1 and 19 are not unpatentable as being obvious over the Ladabaum et al. article in view of the Horner et al. ('652) patent and the Swierkowski ('580) patent.

Dependent Claims 2-8 and 20-26

Claims 2-8 all ultimately depend from independent claim 1, and claims 20-26 all

ultimately depend from independent claim 19. Thus, the allowability of dependent claims 2-8 and 20-26 at least follows from the allowability of independent claims 1 and 19, respectively. As such, claims 2-8 and 20-26 are allowable over the art of record.

In view of the above remarks, Applicants request the withdrawal and reconsideration of the rejections and objections. Applicants respectfully submit that the application is in a condition for allowance, and respectfully request such a Notice.

Conclusion

All objections and rejections having been addressed, it is respectfully submitted that the present application is in a condition of allowance and a Notice to that effect is earnestly solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

CHARGE STATEMENT: The Commissioner is hereby authorized to charge fees that may be required relative to this application, or credit any overpayment, to our Account 03-3975, Order No. 016132-0274779 (SC-007).

Respectfully submitted,

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